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Comment on “Facing the uncertainty of CO₂ storage capacity in China by developing different storage scenarios” by Samuel Höller and Peter Viebahn

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Höller and Viebahn (2016) aim to “provide a systematic overview of the potential for the geological sequestration of CO₂ assessed to date for China”. They describe the purpose of their paper to be “the calculation of the effective capacity as this capacity is the basis for further estimation of matched or practical capacity” and one of the results is named a “China-specific efficiency factor”. Although they “do not undertake basic geological research”, they “provide an overview of existing results by reviewing published studies, and apply the scenario methodology to storage capacities in order to identify the different sources of uncertainty in a transparent manner.”

One of their conclusions is that “the efficiency values are the most important aspect when calculating effective storage capacities”. They were “surprised about the wide range of assumptions and parameter settings (...). However, it was out of the scope of this work to get to the bottom of the considered studies and to verify and improve each assumption, method and parameter involving the authors of the studies.” For the S2 (mid case) CO₂ capacity estimation for saline aquifers in China, they use an efficiency factor of 0.13 (“weighted mean of all efficiency values [based on the analysis of 13 studies] is 13 per cent”).

We consider that an average efficiency factor for saline aquifers in China of 0.13 is based on a misunderstanding of efficiency factors in CO₂ storage and on questionable methodology. We appreciate the author’s openness about the limits of their study but a published “China-specific efficiency factor” factor of 0.13 for saline aquifers based on incomplete understanding of the topic in

a peer reviewed journal requires a critical response. In the following we will show that the methodology of the paper is not based on current best practise. We will start with our main point of criticism, the use of both regional scale and single structure (local) storage efficiency factors.

1) Storage efficiency factors

The efficiency factor in the context of CO₂ storage in saline aquifers describes the proportion of pore space that can be occupied by CO₂. It is very important to differentiate between efficiency factors for entire saline aquifers and those for local injection scenarios in individual structures or traps.

Storage capacity estimates for entire saline aquifers are based on the parameter such as pore volume, solubility and pressure. As mentioned by Höller and Viebahn (2016), open or closed systems can be assumed depending on the geological conditions. However, even in a hypothetical truly open system, the interaction of injection pressure between multiple injection wells will have to be considered. Regional scale efficiency factors from the literature are rather low, in the range of 1-4 % (Bachu et al., 2008) and 0.4-5.5 % (Goodman et al., 2011) for general approaches, and, as an example for a specific saline aquifer capacity estimation, 0.6 % (Heinemann et al., 2012).

Storage capacity estimates for injection into a single structure or trap are very different. Here, a single geological structure (or a part of a saline aquifer) is considered separately from the regional picture. For example, in a recent study on CO₂ storage in an individual anticline in the Southern North Sea, the authors calculate a storage efficiency of 19 % (Pale Blue Dot, 2016). Their study has clearly defined geographical boundaries which are not the geographical limits of the aquifer within which the individual structure is contained. The storage efficiency of 19 % cannot be scaled up to the entire saline aquifer because the study does not consider the regional effects of pressure increase.

Another example to differentiate between aquifer-wide capacity estimations and local injection scenarios is Holloway et al. (2006) and their capacity estimate of the Bunter Sandstone aquifer in the

southern North Sea. They write: “Numerical simulation of CO₂ injection into one [dome] structure (Obdam and van der Meer, 2003; Obdam et al., 2003) indicated a maximum of 40 % CO₂ saturation might be achievable, assuming essentially infinite aquifer communication.” However their storage capacity estimate corresponds to a regional storage efficiency for the Bunter Sandstone saline aquifer of less than 2 %. The difference between the 40 % CO₂ saturation derived from injection into a single structure and the less than 2 % storage efficiency of the entire saline aquifer shown in Holloway et al., (2006) is clear. Yet Höller and Viebahn (2016) do not differentiate between efficiency factors of aquifer-wide capacity estimations and those for local injection scenarios. The two sets of efficiency estimates cannot be considered together, and cannot be meaningfully averaged.

Examining the compilation of efficiency factors of Höller and Viebahn (2016), for one of the source studies it is written that “The results of the CO₂ injection simulation using FEHM presented in the previous session show that the majority of CO₂ saturation ranges from 0.1 - 0.6. The storage efficiency in this study was chosen between 0.1 and 0.6” (Jiao et al., 2011). This is a local efficiency factor. In a second source study, Zhou et al. (2011) calculate the CO₂ storage capacity of the Pearl River Basin (China) saline aquifer using a mid-case efficiency factor of 0.026, which is a regional efficiency factor. Höller and Viebahn (2016) simply combine efficiency factors from the injection simulations to those of the saline aquifer capacity estimation and take an average of the sum. This procedure does not lead to a scientifically meaningful result.

To demonstrate the importance of using only relevant efficiency factors for regional-scale calculations, we calculate the mean efficiency factor using the data provided by Höller and Viebahn (2016) as 0.021. For this calculation, we used the efficiency factors derived from basin –wide analyses (table 3; five studies). We selected the mid case values where three values (high-, mid- and low-case) were given, and the average when two values were given and use an equal weighting for each value. We emphasise the almost order of magnitude difference between our estimate (0.021) and the estimate of Höller and Viebahn (2016; 0.13).

2) The weighting of efficiency factors is not systematic

Efficiency factors from the source studies in the Höller and Viebahn (2016) compilation are differently weighted in the calculation of the average efficiency factor. This is because some storage capacity studies are represented by only a single number, whereas other studies are represented by multiple values. For example, some studies present a mid-, low- and a high-case value for storage efficiency, resulting in three efficiency factors in the Höller and Viebahn (2016) compilation. Other studies produce one value in the compilation. The simple averaging used by Höller and Viebahn (2016) results in a higher impact for a study with three efficiency factors compared to a study with only one efficiency factor. In particular, the storage efficiency of Jiao et al. (2011) of “between 0.1 and 0.6” was represented by Höller and Viebahn (2016) as six individual values (0.1, 0.2, 0.3, 0.4, 0.5 and 0.6). This gives the Jiao et al. (2011) study an unjustifiably high weighting in the calculation of the average storage efficiency. The same method was used for data taken from Jiang and Xu (2010). The irregular weighting of efficiency factors makes the average result of questionable utility.

3) China-specific efficiency factor for saline aquifers

Höller and Viebahn (2016) wrote that “we specially derived a China-specific efficiency factor based on an extensive literature review.”

In terms of area, China is the third biggest country in the world and it comprises many sedimentary basins with saline aquifers of different ages and with different regional geology. To calculate a ‘China-specific efficiency factor’ implies that the Chinese basins share a common geology which separates Chinese basins from the basins in other parts of the world. However, Höller and Viebahn (2016) did not present evidence that this is the case.

Instead, at least one study uses efficiency factors for the calculation of CO₂ storage capacity in saline aquifers which are not specific to China. Zhou et al. (2011) calculated the storage capacity of the saline aquifers in the Pearl River Mouth Basin using efficiency factors from Bachu (2008), the IEAGHG

(2009) and Wildgust (2010). These efficiency factors are not China-specific, they are general values which are used for capacity estimations all over the world. These efficiency factors can be used to calculate the CO₂ storage capacity of basins in China but they are not calibrated by Chinese basins specifically. To use the study of Zhou et al. (2011) to calculate China-specific efficiency factors (if such an efficiency factor exists) is misleading.

Conclusions

Höller and Viebahn (2016) present a literature review of studies on CO₂ storage capacity estimates of geological formations in China without apparently considering the vital distinction between regional and local-scale efficiency factors. In addition, the relative weighting of different studies is not justifiable. In our opinion, the results of their work are potentially misleading if applied to CO₂ storage in China or elsewhere. One of their outcomes, a “China-specific efficiency factor” of 0.13 (mid case), has little scientific justification and should not be applied in future work.

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